CHAPTER 12

PRIVATE FORESTS AND TRANSGENIC FOREST TREES

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Abstract. Molecular domestication of forest tree species is becoming available to corporate timberlands. To what extent other types of forest landowners have access to this technology in the seedling marketplace depends on perceived needs, available information and proof of its safety. Available information must be configured for an increasingly science-illiterate population. Adoption rates of genetically modified (GM) forest trees by U.S. private forest owners with acreages over 1,000 are predicted to be low. GM conifers or other forest tree species enhanced for wood quality, phytomediation, herbicide or pesticide resistance will be less attractive than clonal (non-GM) forest tree species planted for the purposes of wildlife, aesthetics and restoration of heritage trees. With or without GM technology adoption, private landowners must be part of the discussion and policy-making related to commercial-scale use of GM conifers by virtue of the vast forests they control.

1. INTRODUCTION

Genetically modified (GM) or transgenic trees have been promoted as a solution to the loss of biodiversity, preventing insect and disease infestations, remediating pollutants in the environment, reducing tree stress and the chemicals needed to produce paper, carbon sequestration, even a source of fuel and pharmaceuticals (CAMPBELL *et al.,* 2003; FENNING AND GERSHENSON 2002; HERSCHBACH AND KOPRIVA 2002). At the same time, GM trees are being lambasted as a threat to biodiversity via gene escape and introgression into wild gene pools (VAN FRANKENHUYSEN AND BEARDMORE 2004), or because of invasiveness, harm to insects, proprietary ownership by multi-national companies and perceived threat to individual family forests (SFN 2005; LANG 2004). GM trees at present are largely confined to the domain of laboratories and initial field trials where risks and benefits can be intensively studied. Research about the ecological risks of transgenic trees is ongoing yet is scant in comparison to similar studies on the deployment of transgenic crops (VAN FRANKENHUYSEN AND BEARDMORE 2004).

Genomics and the concomitant understanding of gene expression, metabolites and plant physiology are here to stay. GM trees, as research tools, are poised to yield significant insights about plant evolution, wood formation, growth, stress and metabolic functions within plants (HERSCHBACH AND KOPRIVA 2002). With at least 33 genetically transformed forest tree species having already been successfully produced, it appears that once regulatory hurdles are cleared, GM trees could be available in the marketplace within the decade. Following the trend in the horticultural tree crop arena, GM tree research could soon be shifting towards

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modification of traits that are more consumer oriented (DANDEKAR *et al.,* 2002). How, when, and where genetically modified trees reach the marketplace will impact the private forests in the United States.

Private forests comprise 392 million acres in the United States. There are currently over 10.3 million private and family-owned forests nationwide. Owners of more than 100 acres of forestland number only 534,000, yet they control one third of all private forest land, a staggering 139 million acres (BUTLER AND LEATHERBERRY 2004). The importance of private forestlands, especially larger tracts, cannot be overstated, as they have traditionally been the source of public goods (e.g. water, wildlife habitat, and scenic beauty) and a consistent supply of wood fiber and stumpage for the forest products industry. Private forests, and the renewable resources they generate and protect, are critical to employment, sustainability and viability of many rural economies. Urbanization, globalization, corporate mergers and shifting overseas production threatened traditional domestic markets and, thus, the stability and viability of private forests. Concerns about the sustainability and viability of domestic private forests fuel both the development and the discouragement of the technology behind GM trees.

Understanding the needs and motivations of private forest landowners yields insights into their likelihood of adoption and potential support for GM trees. This chapter provides a review of the steps that precede innovation adoption as a precursor to a discussion on the involvement and education of private forest landowners about GM tree development and deployment. Predictions of GM tree products likely to be popular with private forest owners are advanced. Suggestions for additional opinion research are made in an effort to ascertain which GM solutions may provide the greatest public benefit and appeal for private forests and their owners.

2. WHERE DO PEOPLE STAND ON GM TREES?

Discussions about the promise or potential problems of genetically modified trees have largely taken place outside of the media. The GM tree debate has been confined to its proponents, researchers, regulators, academics and the organized community of opponents. The GM tree debate is a present-day example of what HOBAN (2000) describes as *social arena theory,* whereby interest groups try to sway public policy in directions that support their own self-interest. As with other controversies, the protagonists and antagonists involved in the in public debate reflect opposing sides of a continuum. Typically, as in this instance, somewhere in the middle exist the vast majority of consumers who exhibit little interest or concern about the technological risks until such time as they are directly impacted by them (e.g. food as it relates to GM crops).

The discussions about the potential merits and detriments of GM trees are still in their infancy, and reflect the fact that experimental plants exist only within laboratory and a few field test sites. The debate is largely academic and hypothetical by necessity, because the technology is too recent to truly study its impact. Many opponents believe that a moratorium is needed to allow for the study of all potential impacts (transgene spread, non-target impacts, ecosystem and gene stability). It is

the very lack of knowledge about how transgenes interact with the environment that impedes public confidence and regulatory approval that can lead to commercial release (van FRANKENHUYSEN AND BEARDMORE 2004).

The phenomenal advances in genomics and new techniques (microarrays, automated sequencing, genetic transformation) have in many ways outpaced the ability of our current intellectual and regulatory systems to process them. Other chapters in this volume provide updated overviews of the present regulations of transgenic releases. Moreover, the science and techniques required of this emerging science is complex and requires a significant investment of time and resources simply to understand and be conversant in this emerging area of science. The potential impacts of GM trees on private lands and owners have yet to be fully explored, yet opinion research on agricultural biotechnology can yield insights about likely acceptance of GM trees.

The controversy surrounding the release and trade disputes about GM crops provides insights into the likely acceptance of transgenic trees. An insightful, historical account of the development GM crops, their release in the U.S. and opposition in Europe is detailed in a popular press book entitled *Dinner at the New Gene Cafe* (LAMBRECHT 2001). Clearly, a difference in acceptance exists within and across societies and nations. HOBAN (2000) noted that 15% of U.S. consumers listed biotechnology as a serious food risk over a three-year survey period. Conversely, three-quarters of those same consumers rated microbial contamination and nearly two-thirds rated pesticide residues as serious food hazards during the 1995-1997 time frame. HOBAN (2000) also noted a consistently higher perception (rating) of serious food hazard risk of GM foods by Europeans compared to U.S. consumers. Forty-four percent of Europeans respondents rated genetic engineering as a serious food hazard. HOBAN (2000) acknowledges that consumer attitude toward transgenic technology is related to general beliefs about science, technology and food and thus was rather negative about the prospects for food biotechnology in Europe.

Table 1. U.S. Total Forestland Acreage by Broad Ownership Type, Region, 2003.

REGION	PRIVATE	PUBLIC	TOTAL
North	128,317,000	41,368,000	169.685,000
South	188,845,000	25,758,000	214,603,000
West	75,569,000	160,448,000	236,017,000
United States	392,730,000	227,574,000	620,305,000

2.1. Extent, Size and Importance of Private Forests

United States forests cover 620 million acres, of which 392 million acres are in private ownership (SMITH *et al.,* 2004; Table 1). More than one half of all private forest acreage, nearly 189,000,000 acres, is located in the South. Private forests

located in the northern and central states comprise roughly a third or 128,000,000 acres of the U.S. private forestland. The remainder of the private forests are located west of the Mississippi River and account for more than 75,000,000 acres.

Family ownership accounts for 261 million acres, more than one in three of the nation's forested acres. Business interests control approximately 131,000,000 forest acres, one-third of all private forests (BUTLER AND LEATHERBERRY 2004; SMITH AND VISSAGE 2004). Private forestlands outnumber corporate holdings by 2 to 1 in the North and South, whereas in the Western half of the United States private forests approach parity between family and business ownership. Note the dominance of Southern forests in both business and family ownership.

Table 2. Private U.S. Forestland Acreage by Region, 2003 (Butler and Leatherberry 2004; Smith et al. 2004).

REGION	FAMILY	BUSINESS	TOTAL
North	93,866,000	34,451,000	128,317,000
South	127,559,000	61,286,000	188,845,000
West	40,215,000	35,354,000	75,569,000
United States	261,639,000	131,091,000	392,730,000

2.2. Large Private Forests

A strong relationship exists between the size of forestland holdings and observed probability of seeking management advice and harvest timber (BUTLER AND LEATHERBERRY 2004). Larger forest ownerships undoubtedly offer economies of scale not typically available to smaller tracts. Moreover, a business-like approach is required of larger ownerships simply because few entities can afford to amass or maintain larger forests without systematic timber receipts or other incomes flows derived from management. As we shall review later, large ownerships have been positively correlated with education, socio-economic class, education and other variables to forest management adoption. If GM trees are viewed simply as a new innovation for forest management, it is likely that larger ownerships will deploy them first and most successfully. The dominance of large private forest ownership and acreage within the Southern region suggest that GM trees or similar innovations may have greater acceptance there, as opposed to other regions within the United States.

Table 3. Size Distribution, Number and Acreage (in Millions) of U.S. Large Private Forest Ownerships By Region, 2003 (Source: BUTLER AND LEATHERBERRY 2004).

Acreage Class	*Northern Owners (acres)*	*Southern Owners (acres)*	*West Owners (acres)*	*U.S. Total Owners (acres)*
100–499	180,000 (29.9 M)	243,000 (43.9 M)	64,000 (11.7 M.)	487,000 (85.74 M)
500–999	6,000 (3.6 M.)	18,000 (11.1 M)	9,000 (5.6 M)	33,000 (20.3 M)
1000–999	2,000 (2.7 M)	8,000 (13.7 M)	4,000 (7.5 M)	14,000 (24.0 M)
5000 +	< 1,000 (1.5 M)	< 1,000 (5.5 M)	< 1,000 (2.3 M)	1,000 + (9.3 M)
Total	< 189,000 (37.8 M)	< 270,000 (74.4 M)	< 78,000 (27.2 M)	535,000 (139.3 M)

Note: Data may not add to totals because of rounding.

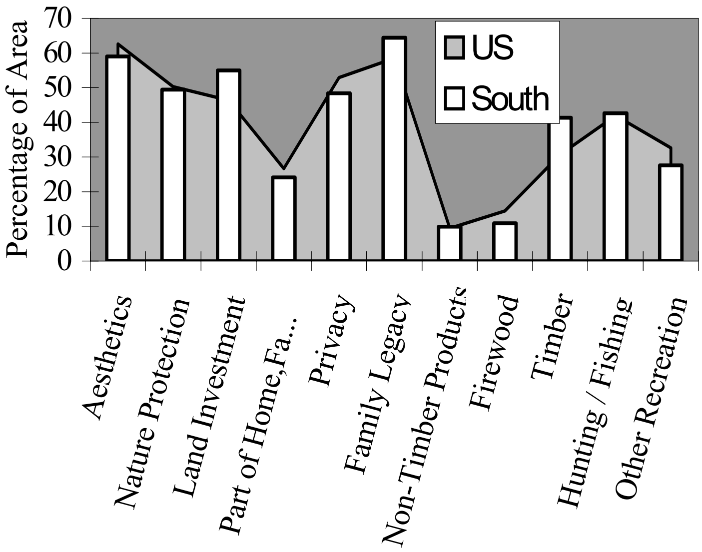
2.3. What Motivates Private Forest Landowners?

With a population of 10 million and rising, individual private forest landowners in the U.S. nearly defy categorization. Most private forest landowners have multiple reasons for owning their forests, yet four reasons predominate: 1) part of their home or farm; 2) maintaining the natural, aesthetic nature of their holdings; 3) recreational purposes; and 4) maintaining a family legacy (BUTLER AND LEATHERBERRY 2004). Interestingly, the order and primacy of these ownership objectives have not changed appreciable in the last decade (BIRCH 1996)

Private landowners in the American South differ from national ownership objectives on three key areas: land investment, family legacy and timber production. By viewing these differences on an acreage or area basis the objectives of the largest landowners gain prominence. Timber production as an ownership objective historically ranks near the bottom of most survey results. The southeastern United States follows this same trend when viewed in terms of ownership numbers, yet when interpreted on an area or acreage basis, timber production ranks third in reason for ownership (Figure 1). Regional differences are clear: Timber production is very important or important to landowners that control 4 in 10 forest acres in the South (BUTLER AND LEATHERBERRY 2004). The importance of timber as an ownership

objective on larger tracts is well documented and has ramifications for technology transfer and deployment of GM trees as will be discussed in more depth below.

Figure 1. Comparison of Ownership Objectives by Area of U.S. versus Southern Family-Owned Forest Land (Source of Data: NWOS, 2003).



3. INNOVATION-DECISION PROCESS AND GM TREES

The innovation-decision process applies to the introduction of transgenic forest trees to private forest owners. It refers to a series of actions and choices by which an individual or entity evaluates a new idea and determines its suitability to their business or personal activities (ROGERS 2003). It begins once the awareness or knowledge of an innovation is received. A person, upon becoming aware of an innovation, forms an attitude about it, followed by a decision to adopt or reject it. If the decision is favorable, then the innovation can be implemented in its present form. If judged unfavorably, then the innovation can be modified to suit situation or need during the implementation stage or simply dismissed outright. A confirmation period typically follows innovation adoption, where reinforcement of the decision is sought. Should confirmation fail, individuals may reverse the decision to undertake an

innovation. Reversals would likely follow the receipt of conflicting contradicting, or unfavorable messages about the innovation.

The innovation-decision process is theorized to include decision stages, as shown below in a linear, orderly progression (Figure 2). In actuality, the acceptance and adoption of innovations may be less systematic, returning to its beginning or a previous step as additional information or insights occur.

Figure 2. The Innovation-Decision Process (ROGERS 2003).

knowledge ⇨ persuasion ⇨ decision ⇨ implementation ⇨ confirmation

Knowledge – The knowledge stage constitutes the first exposure to an innovation or practice. Some debate exists over whether the exposure to an innovation is accidental or actively sought by an individual. ROGERS (2003) notes that individuals generally tend to expose themselves to ideas that are in accordance with their interests, needs or existing attitudes and avoid discordant messages. When an individual is unaware of an existing or potential need, a change agent may help to increase awareness of that need or how the innovation can address that need directly. In other cases, a change agent can advance the understanding of an innovation in an effort to increase its adoption.

An advice source or change agent for private forest landowners can be as varied as a professional forester to a fellow landowner. In the recent NATIONAL WOODLAND OWNER SURVEY (2003), more than one in five US southern family forest owners identified state forestry and private consultants as their advice source. Less than ten percent of those same landowners identified federal agency, industry or extension as their source of advice (BUTLER AND LEATHERBERRY 2004b). Information processed during the knowledge stage is cognitive in nature (e.g. how-to information or principles of how the innovation works). Should public and private foresters become *de facto* GM trees advice sources, then a wholesale continuing educational effort would be required before any wholesale adoption could be realized.

Persuasion – During the persuasion stage, an individual forms a favorable or unfavorable attitude about the innovation. Individuals actively seek information during the persuasion stage, in contrast to the passive way in which they received knowledge about the innovation itself. A general perception is formed of an innovation and the perceived attributes are judged based on their relative advantage, compatibility, and complexity.

Individuals will think hypothetically about the merits of an innovation. Persuasion can take place individually and might entail reading, discussions and assessment of the risks and uncertainties as they compare to anticipated benefits. If the envisioned benefits outweigh the anticipated risks the individual may be

persuaded to adopt the innovation. Peers are the preferred source for much of the information used to decide whether to adopt or reject an innovation. Unlike the thinking style used during the knowledge stage, the affective or feeling style is more commonly used during the persuasion stage (ROGERS 2003).

Decision – The decision stage occurs when an individual or entity chooses to adopt or reject an innovation. Often the decision process can include a small scale trial or 'trial by others'. Trials can minimize the risk or uncertainties associated with an innovation. Successful demonstration or small scale testing of GM trees by private landowners would be an essential component of a technology transfer effort, especially at this critical decision stage.

Implementation – Putting an innovation into place marks the implementation stage. During this stage, time and resources are invested to seeking information that can help avoid or overcome problems typically encountered with innovation implementation. The length of the implementation stage varies with the complexity of the innovation, its availability, and the extent to which modifications (reinvention) are necessary (ROGERS 2003). The implementation phase is complete when an innovation becomes standard, or routine.

Confirmation - The confirmation stage marks an individual's attempt to reinforce their innovation decision after it has been made. The confirmation process is an attempt to quell or eliminate any dissonance that an adopter feels about their decision. This second-guessing approach can stem from the size of capital investment, fears about the future, and the negative messages and rumors about the drawbacks of an innovation.

4. CHARACTERISTICS INFLUENCING LANDOWNER USE OF NEW INNOVATIONS

The perception of the benefits and drawbacks of innovations can help explain the rate of adoption by individuals. Understanding the five key characteristics, by which individuals and entities evaluate innovations, can facilitate better prediction of the adoption of forestry practices or participation in incentive programs. More than half, and as much as 87% of the variance in rate of adoption of innovations can be explained by the perceived attributes described below (ROGERS 1995, 2003). Innovation characteristics collectively determine the manner in which an individual will perceive the 'total package' – a sure thing, on one hand, or a risky bet, on the other.

Figure 3. Perceived Attributes of Innovations (from ROGERS 2003).

Relative Advantage	the degree to which an innovation is perceived as better than the idea it supersedes.
Compatibility	the degree to which an innovation is perceived as consistent with existing values, past experience, and the needs of potential adopters.
Complexity	the degree to which an innovation is perceived as difficult to understand and use.
Trialability	the degree to which an innovation may be experimented on a limited basis.
Observability	the degree to which the results of an innovation are visible to others.

Relative advantage is synonymous with 'what's in the best interest of the potential adopter.' The extent to which GM trees reward or benefit landowners will ultimately impact his/her decision to adopt. Individuals weigh the potential benefits by measures familiar to them: profitability, low relative cost, and quick return. HAYMOND (1988b) found the importance of quick monetary return to be a significant predictor of silvicultural practice adoption by opinion leaders in South Carolina. Commercial thinning and timber stand improvement, both yielding income, were used by the vast majority of landowners in her study. Yet adoption isn't always about money *per se*. Relative advantage of forestry practices, like GM trees, relates to how well those practices match the non-timber desires of landowners. Improvement of other uses (other than timber) was found to be a significant attitudinal variable for predicting silvicultural practice use by opinion leaders in South Carolina (HAYMOND 1988b).

New ideas and forestry practices must be compatible with the values, needs, and experiences of potential adopters. Furthermore, the delivery or communication of innovative practices by foresters and resource professionals must be made with respect to the norms or beliefs of the potential adopters. ROGERS (2003) details the importance of homophily in the flow of communication of innovations, that is, individuals are more apt to act upon information received from people who are like them. Thus potential purveyors of GM forest tree technology must be viewed as of the same mind as potential adopters.

The degree to which an innovation is perceived as difficult to understand and use has been a persistent barrier to adoption. Simplicity in message of the benefits and rewards of an innovation are critical to its adoption. New ideas are slow to become accepted, as was the case with improved genetics of pine trees, because of the long time period required to demonstrate success (ZOBEL AND SPRAGUE 1993). GM trees will succeed or fail based on how well they are understood and presented to potential users.

The degree to which forestry management may be tested on a pilot scale is central to the missions of extension and technical assistance to private landowner.

Limited trials of GM technology via single trees or small plots with limited inputs, will likely receive greater acceptance (e.g. heritage tree restoration or clonal wildlife mast tree). Whereas, GM trees with improved growth, strength or quality traits will require intensive site preparation, fertilization and herbicides for controlling competing vegetation to fully succeed. Such trials will lag in adoption rates by all but the most intensive managers who have the necessary capital, expertise and resources.

Observations of most forest practices typically occurs at the macro scale and may take a decade or more to become apparent. When an open field is planted to pines the result is evident in a few years. Other cultural treatments (herbicides, bedding, thinning) may be more difficult to discern without a comparison treatment nearby. Companies or entities with a mission to promote GM trees and technology would advance their cause greatly by providing observations at the forefront of their promotional activities. Therein lies the dilemma: promotion of GM fields and even greenhouse trials can lead to their untimely destruction by radical opponents who may destroy the plant materials or the laboratory itself.

4.1. Innovation vs. Diffusion?

The value of an innovation-decision model is its ability to describe the component parts of the adoption process, and its near universal applicability across cultures (FEDER *et al.,* 1982). Diffusion refers to the process by which new ideas are communicated and is central to the innovation-decision process. Diffusion research explores the manner in which an innovation is communicated through certain channels, over time, among the members of a social system (ROGERS 2003). Alerting potential adopters of GM forest tree merits can succeed or fail largely on how information diffusion takes place and by whom.

The adoption of an innovation is primarily an outcome of the learning or communication process (BROWN 1981). Diffusion research seeks to identify and examine effective information flow, the characteristics of that flow, how the information is received, and resistance to adoption. Communication channels describe the manner in which messages are transmitted between individuals. The relationship between individuals impacts the nature of information exchange and ultimately, the receptivity or likelihood of innovation adoption.

Two types of communication channels are advanced by diffusion research: mass media, and interpersonal communication. Each channel type is further subdivided by its source: local or cosmopolitan. Mass media raises the awareness or knowledge level about an innovation. Mass media communication can rapidly reach large audiences, create knowledge and spread information. At best, mass media can change weakly-held attitudes. Mass media is important at the knowledge stage and can prompt innovators to try a new idea, especially in developed countries but to a much lesser extent in the developing world.

Interpersonal channels describe the information exchange between or among individuals. Interpersonal communication can form and change strongly held beliefs. Interpersonal communication is the dominant manner by which late adopters learn about innovations and persuaded to adopt them. Two-way exchange of information

allows for the clarification and the breaching of social-psychological barriers that influence perception, retention, and exposure to the benefits of an innovation (ROGERS 2003). Late adopters are unlikely to be swayed by mass media communications because media lack persuasive power to motivate. Thus, late adopters rely on interpersonal channels nearly exclusively when deciding to adopt an innovation.

Cosmopolite communication channels originate from outside a social system are important to the knowledge phase of innovation adoption. These sources may include national and regional press, university research, farm shows and exhibitions. External communication is of lesser importance in the persuasion stage. Localite sources, in contrast, increase in importance during the persuasion stage, especially for later adopters. Should GM trees be made available to private forest landowners the use of local communications channels will be of paramount importance to late adopters, especially after early adoption has taken place.

MUTH AND HENDEE (1980) stress that new information flow in social systems is non-random; key individuals are sought out for information, opinions, and suggestions. Through key opinion leaders, innovations are diffused laterally to their peers. The basic tenet of diffusion strategy is that individuals may be persuaded to adopt through communications, both through a change agent and media communications (BROWN 1981). DOOLITTLE AND STRAKA (1987) confirmed the greater likelihood of changing client perception about forest regeneration using interpersonal communications, rather than by impersonal means. The authors note that late adopters were less likely to belong to highly interconnected social systems, were more clannish, and exhibited little contact among groups than did early adopters. They advise that personal contacts or individual mailings be employed to inform non-industrial private forestland owners.

Personal contact is more effective than targeted mailing or mass media in transmitting specific NIPF management advice to Michigan forest landowners (WEST *et al.,* 1988). Their data showed that mass media had almost no effect on adoption of NIPF practices. They found that peer-based information and advice was received about as often as contact from professional foresters or from mass media. The importance of sound, effective management advice transmitted through carefully selected opinion leaders was stressed. The implications for GM tree advocates and detractors are clear: that opinion leaders are the key to reaching private forest owners.

4.2. Characteristics of Active Management Forest Landowners

The forestry research literature is replete with studies of the explanatory factors or characteristics of nonindustrial private forest landowners linked to propensity to reforest, harvest timber or manage for timber production (ROYER AND KAISER 1983; GREENE AND BLATNER 1986; ROYER 1987, ROYER AND MOULTON 1987; HYBERG AND HOLTHAUSEN 1989; HARDIE AND PARKS 1991; NAGUBADI *et al.,* 1996; RATHKE AND BAUGHMAN 1996). Input from sociological theory, like innovation adoption behavior, has been scant in forestry research. This is particularly problematic because forest management activities are truly classified as innovations (GRAMANN 1984).

Early studies of the adoption characteristics of woodland owners (SOUTH *et al.,* 1965; SOLLIE 1965) established positive relationships between forest management practice adoption and certain demographic or land characteristics (Table 4).

Table 4. Characteristics of landowners and relationship to active forest management.

Characteristic	*Relationship / Correlation*
Education	Positive
Acreage (Farm and Woodland)	Positive
Attitude Toward Woodland / Forest Conservation	Positive
Occupation of Type of Farmer / Owner	Varied
Use of Outside Information	Positive
Use of Numerous Information Sources	Positive
Socio-economic Status or Rank	Positive
Knowledge of Cost-share Assistance	Positive
Source of Family Income from Farm	Positive

Recent diffusion research on pine regeneration conducted in Alabama (DOOLITTLE AND STRAKA 1987) confirmed many of ROGERS (2003) generalizations about the characteristics of early adopters. Early adopters were found to have more education, higher social status, larger production units, a commercial - economic orientation, more specialized operations, favorable attitude toward credit, and higher level of importance placed on timber management. Several variables were found to be positive and significant in explaining landowner regeneration behavior following harvest on pine sites (Table 5).

Table 5. Explanatory Variables of Southern Landowners Linked to Pine Regeneration and Silviculture Practice Implementation (DOOLITTLE AND STRAKA 1987 and HAYMOND 1988a, respectively).

ExplanatoryVariable	Statistical Significance
PINE REGENERATION	
Venturesome Rating	$p < .05$
Innovative Rating	$p < .05$
High School Graduate	$p < .05$
Timber Management Important	$p < .01$
Income Above $15,000/ year	$p < .01$
Opinion Leadership (self-rated)	$p < .01$
Owned Over 100 Acres	$p < .01$
SILVICULTURAL PRACTICES	
Size of Forest Landholding	$p < .01$
Importance of Quick Monetary Return	$p < .01$
Importance of Improvement for Other Uses	$p < .02$
Importance of Increase Timber Production	$p = .09$

Adoption research of silvicultural practice use by South Carolina opinion leaders suggest that a timber orientation and costs of adoption may not fully explain adoption behavior to the extent that earlier studies have surmised. The importance of forest improvement for non-timber uses is clear and significant for the landowners in their study region. The apparent increased adoption behavior of multi-objective landowners was also found in a study of Finnish forest owners (KUULUVAINEN *et al.,*1996) and for Missouri private forest owners of mixed-objective typology as defined by KURTZ AND LEWIS (1981).

5. UNCERTAINTIES AND THE FUTURE OF GM TREES PLANTED ON PRIVATE FORESTS

Transgenic or GM forest trees and the promise that they may hold for private forestland are locked at a scientific and social crossroads. Before private forests can be a part of the restoration of American chestnut, carbon sequestration or other public benefits, broad-scale education and support must take place. More research is needed about the potential risks, benefits and ethics associated with GM tree deployment (GRESSEL AND ROTTEVEEL 2000; THOMPSON AND STRAUSS 2000). And from the author's perspective, that research and its subsequent dissemination must focus on the economic, ecological and sociological perspective both in the developed and undeveloped world. A wealth of resources has coalesced around forest tree biotechnology and its potential commercial uses in general.

Additional public support can be garnered and sustained as this technology portfolio is focused on environmental and energy concerns of greater society. The subject of forest trees galvanizes many political causes ranging from individual rights, economic viability to environmental justice. A serious and deliberate assessment of the risks associated with the deployment of GM trees may not quiet all opposition. To address that likely scenario, all efforts to ensure biosafety through regulation and agency oversight must be transparent and coordinated (MCLEAN AND CHAREST 2000; MULLIN AND BERTRAND 1998). In addition, the exploration of ethics for tree biotechnologists related to procedures, unintended consequences and intellectual property rights is warranted (THOMPSON AND STRAUSS 2000).

YANCHUK (2001) suggested that research and development conducted by forestry biotechnologists will largely be used in support of advancing clonal forestry. Initial deployment of GM trees will, by necessity, occur in the countries with the most experience with clonal and exotic forestry. GM trees are not likely to follow the rapid adoption observed in GM crops in the United States, at least not on national and private lands. That being said, it is important to note that clonal forestry has finally arrived on the North American continent. A commercial supply of clonal forest trees, produced via somatic embryogenesis (SE) from non-GM conifer stock, was sold to industrial and private landowners during the 2004 planting season (ATTREE 2004)

Currently, SE clones cost 8 to 10 times conventionally grown seedlings but potentially have captured a quantum leap of genetic gain over their fertilized brethren. As anticipated cost savings result from the increased production of clonal plantlets, a viable platform for DNA recombination will emerge. LIBBY (2004) speculates that clones will become the norm for intensive plantation management. Continued advances in propagation technology, supported by conventional tree-breeding programs will synergistically culminate in use of genetically engineered specific clones (LIBBY 2004). Assuming GM trees can successfully pass deregulation for an unconfined release, they may become a fixture in the world's forested landscape within the decade, if not sooner. Should GM trees become deregulated for open release in the United States, their theorized acceptance might follow the projected schedule (Table 6).

SALLEH (2001) offers a more robust prediction for GM trees in Asia and the Pacific, complete with finite milestones:

> " In 2050, a new transgenic tree that grows fast, absorbs carbon efficiently and produces edible shoots and fruits will be undergoing genetic modification to produce sap that can be used as fuel to drive automobiles without any processing. Scientists will aim to start economic production of this fuel by the year 2075."

Whether or not we will see a fuel derived directly from GM forest trees is anyone's guess. What is certain is that the molecular domestication of several commercial tree species is at hand. To what extent GM technology is to be brought to the marketplace depends on societal need, support and proof of its safety to an increasingly science-illiterate populace. The private landowners, by virtue of the

forests they control, should be part of the discussion and ultimate decisions related to use of GM trees.

Table 6. Predictions for GM tree adoption by United States private forest owners with acreage over 1,000 (i.e. probable early adopters).

Innovation Type	Near term	Long term
Clones w/ Novel Traits for Beauty Enhancement or Wildlife (mast-fruit)	Medium	High+
Clones w/ Novel Traits for Restoration/ Heritage trees	Medium	High+
Clones w/ Novel Traits for Growth Enhancement	Low-Medium	Medium*
Phytoremediation	Low	Medium-High*+
IR – Insect Resistance	Low	Medium*+
HR- Herbicide Resistance	Low	Low-Medium*
LM- Lignin Modification	Low	Low-Medium*

* With favorable licensing, availability and awareness of successful trials or demonstrations
\+ Site Specific Locations

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